The Advanced Test Reactor Capabilities Overview

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June 2009

Idaho National Laboratory

ATR
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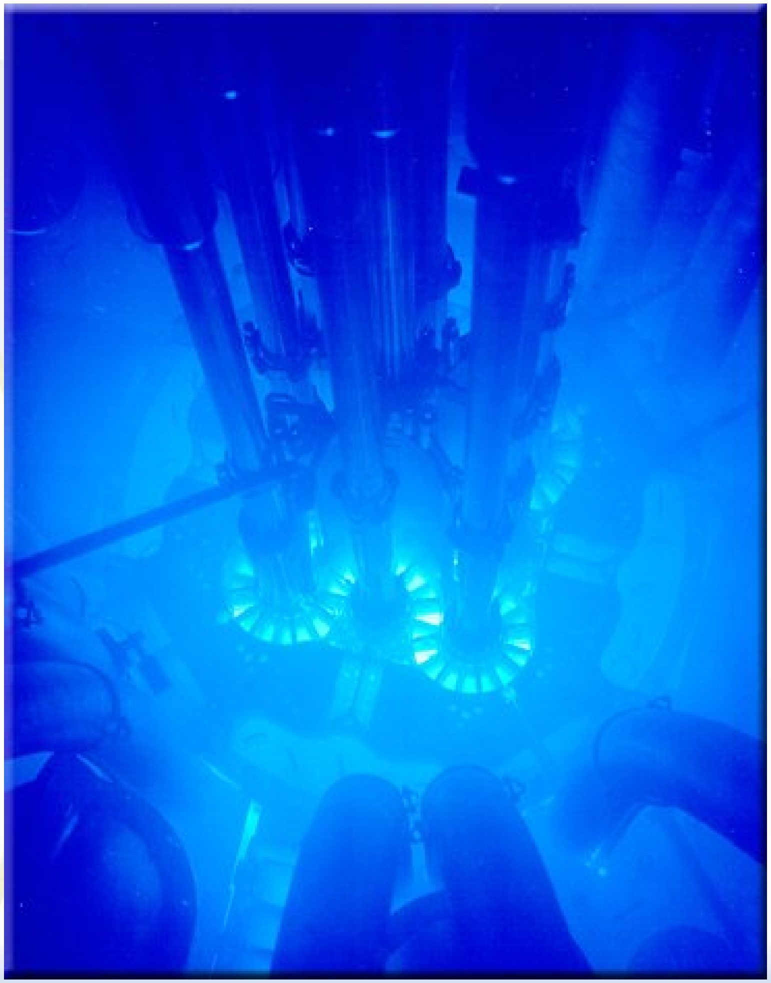
Outline of Presentation

- **Advanced Test Reactor (ATR) Description**
- **Unique Design Features**
- **ATR Test Configurations**
  - **Static Capsule**
  - **Instrumented Lead**
  - **Pressurized Water Loop**
  - **Hydraulic Shuttle**
- **Proposed Enhancements**
- **Test Train Assembly Facility**



Historical Perspective

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<u>Materials Test Reactor (MTR)</u>

- 1952 through the early 1970's
- First of its kind to study material behavior in a radiation field

<u>Engineering Test Reactor (ETR)</u>

- 1958 through the early 1980's
- Studied fuel performance and reactor components, including sodium reactor experiments

<u>Advanced Test Reactor (ATR)</u>

- Initial operation in 1967 – continuous operation until present
- Fuels and materials development for the Naval Nuclear Propulsion Program, the Department of Energy, and others

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ATR Description

Reactor Type

250 MWt design

Pressurized, light-water moderated and cooled; beryllium reflector

Reactor Vessel

12 ft (3.65 m) diameter cylinder,

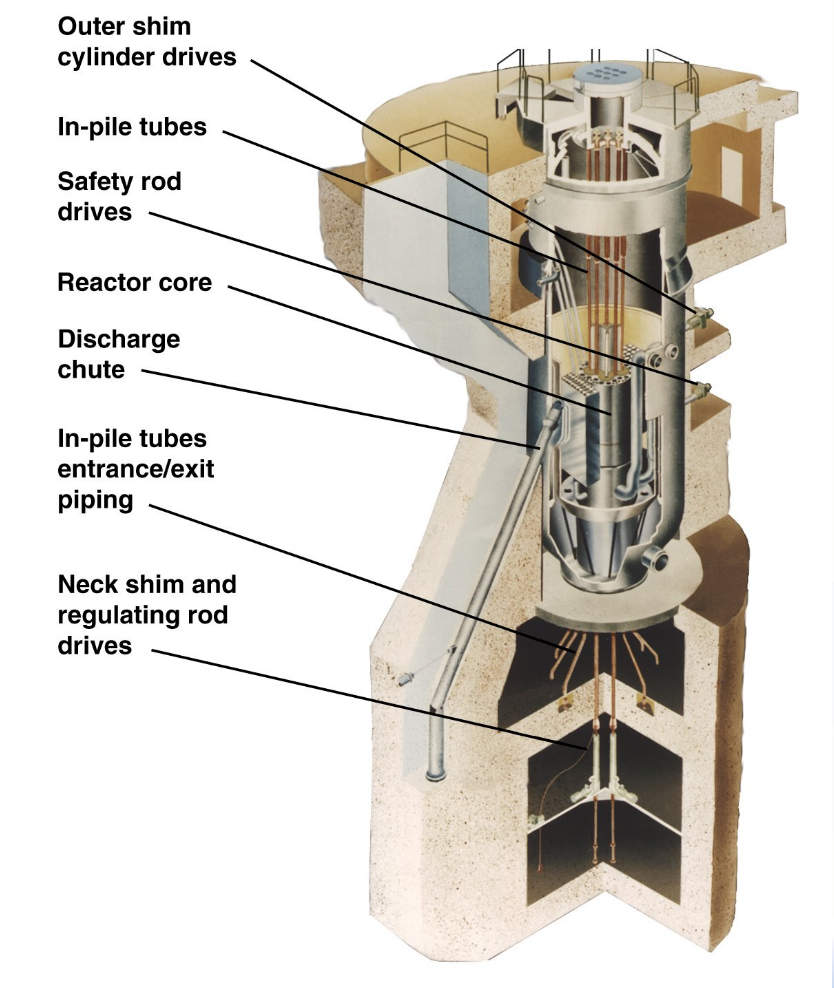
36 ft (10.67 m) high

stainless steel

Maximum Flux, at 250 MW

1 x 1015 n/cm^2-sec thermal

5 x 1014 n/cm^2-sec fast



ATR Operating Parameters

Core

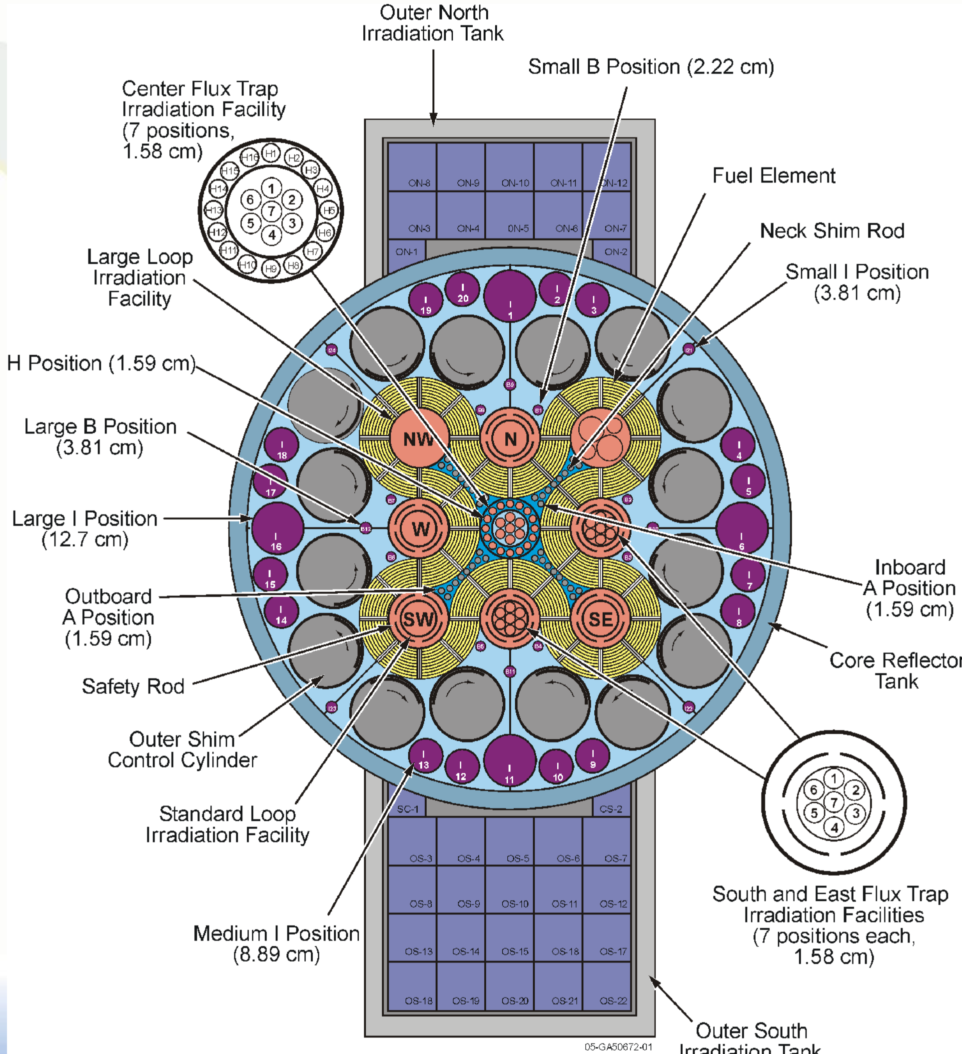
• Active Fuel Length	4 ft
• Fuel Assembly - metallic fuel, Al clad	40 fuel assemblies
• Number of Fuel Plates per Assembly	19
• U-235 Content of an Assembly	1,075 g

Coolant

• Design Pressure	0.7 MPa (390 psig)
• Design Temperature	115°C (240°F)
• Reactor Coolant	Light Water
• Maximum Coolant Flow Rate	3.09 m^3/s (49,000 gpm)
• Coolant Temperature (Op.)	< 52°C (125°F) inlet, 71°C (160°F) outlet

ATR Core Cross Section

- Test size - up to 5.0" D.
- 77 Irradiation Positions:
  - 4 Flux Traps
  - 5 In-pile Tubes
  - 68 in Reflector
- Hafnium Control Drums
  - Flux/Power Adjustable Across Core
  - Maintains Axial Flux Symmetry



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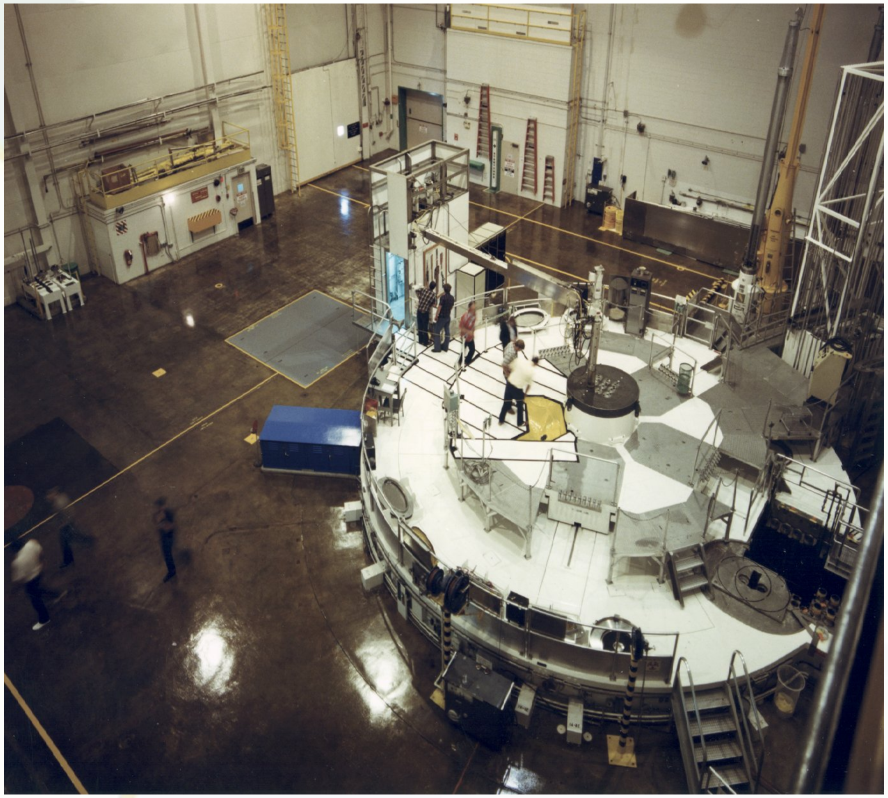
ATR Operations

- Operating Cycles
  - Standard operating cycle is 6 to 8 weeks
  - Occasionally short high power cycles of 2 weeks
  - Standard reactor outages are 1 or 2 weeks
  - Operations for approximately 250+ days per year
- Core Internals Changeout every 7 to 10 years
- ATR Critical Facility – used for reactivity measurements



Unique Design Features

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- Combination of high flux and large test volumes
- Symmetrical axial power profile
- Power tilt capability between all four corners of core ($\leq$3:1 ratio) – different testing conditions for multiple tests during same operating cycle
- Individual experiment parameter control for multiple tests in a single irradiation position
- Individual experiment temperature, pressure, flow, and chemistry control in five separate test loops
- Accelerated testing for fuels – up to 20x actual operation time for some fuel types
- No design limited lifetime: expected to operate for many more years
  - Core internals changeout (CIC) outages
  - Large stainless steel reactor vessel – minimal embrittlement

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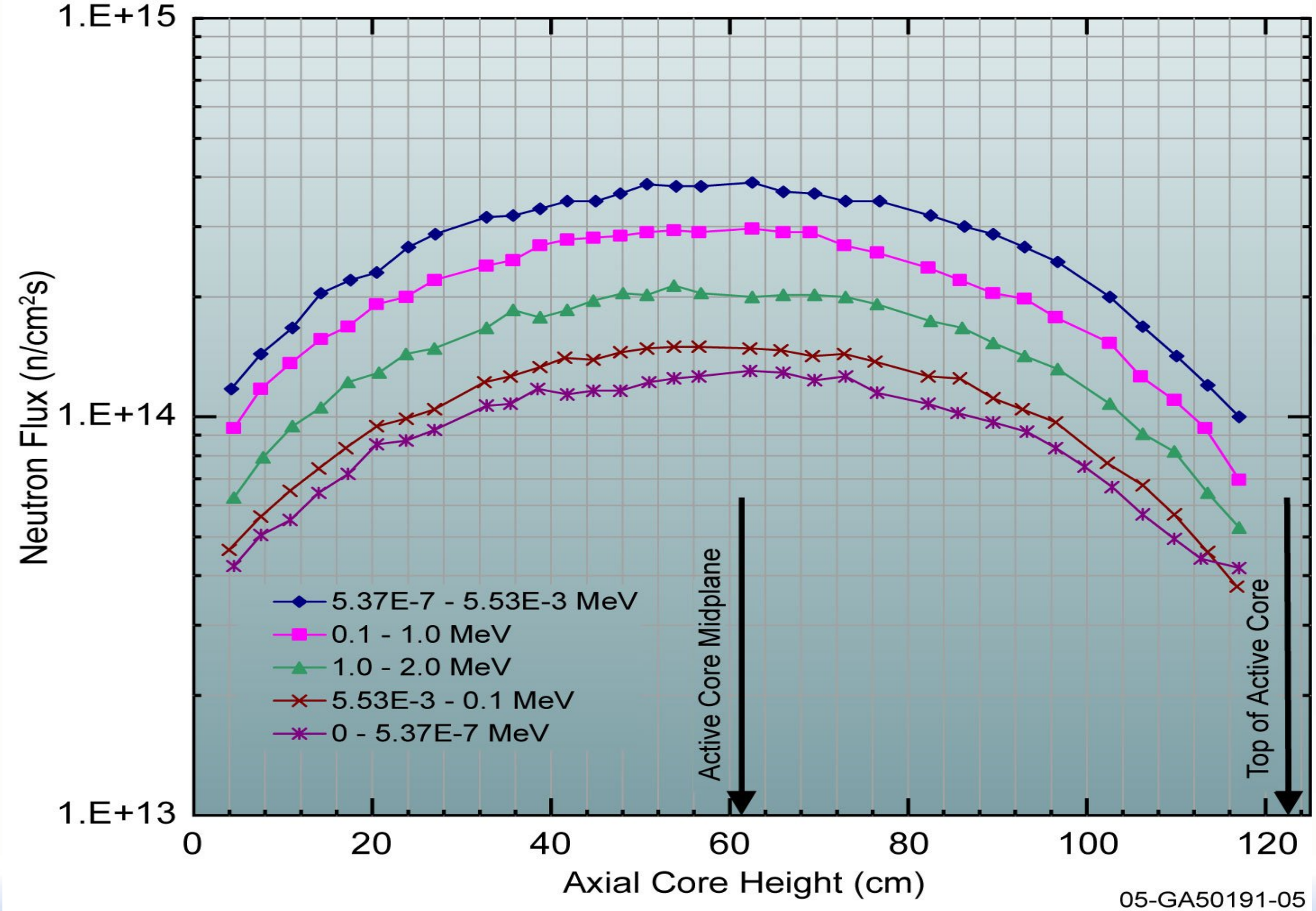
Center Flux Trap Flux Profile (125 MW)



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Comparison between ATR and Power PWR

Reactor Features	ATR	PWR (Typical)
Power (MW_{th})	250 (Max Design)	~ 3,800
Operating Pressure (psig)	~ 355	~ 2235
Inlet Temp. (F)	~ 125	~550
Outlet Temp. (F)	~ 160	~620
Power Density (kW/ft^3)	~ 28,300	~ 2,800
Fuel	Enriched U-235	3 – 4 % U-235
Fuel Temp. (F)	~ 462	> 1000

Experiment Configurations

Simple Static Capsules

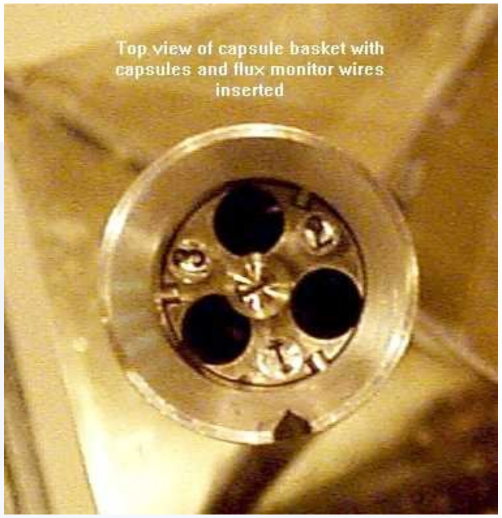
- Reflector positions or flux traps
- Isotopes, structural materials, fuel coupons or pellets

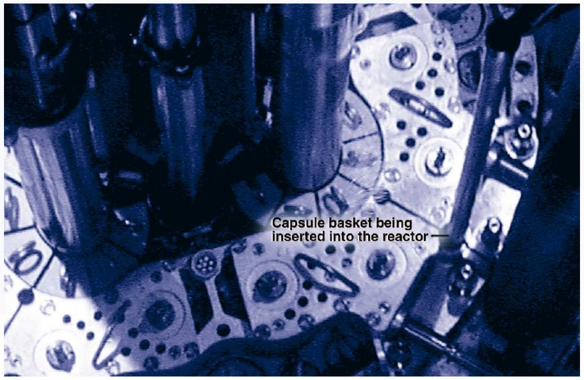
Instrumented Lead Experiments

- On-line experiment measurements
- With or without temperature control
- Structural materials, cladding, fuel pins

Pressurized Water Loops

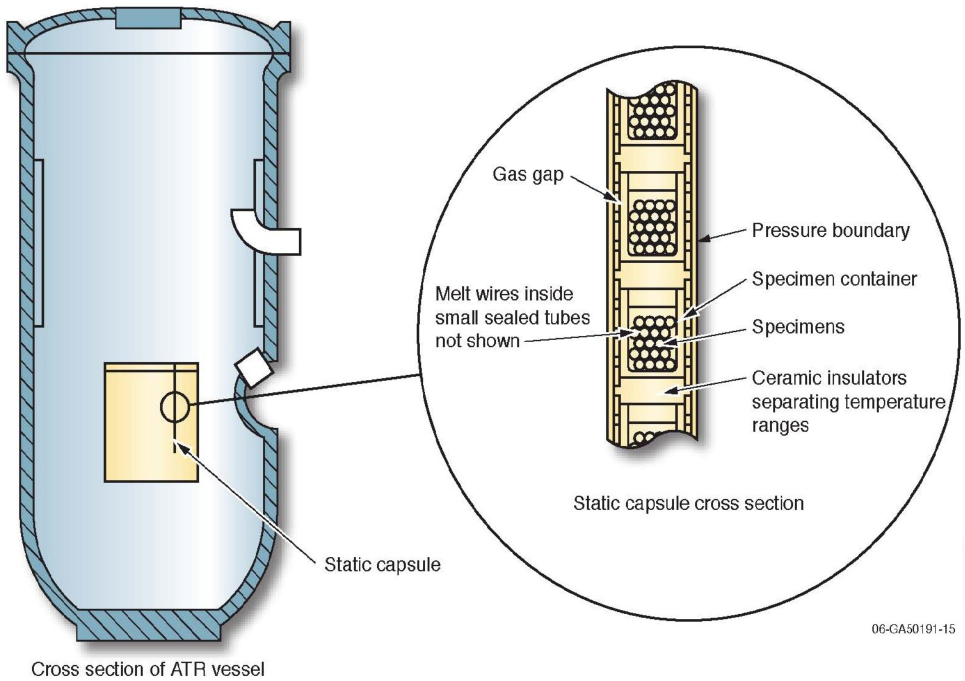
- Five presently installed in flux traps
- Control pressure, temperature, chemistry
- Structural materials, cladding, tubing, fuel assemblies





Simple Static Capsule Experiments

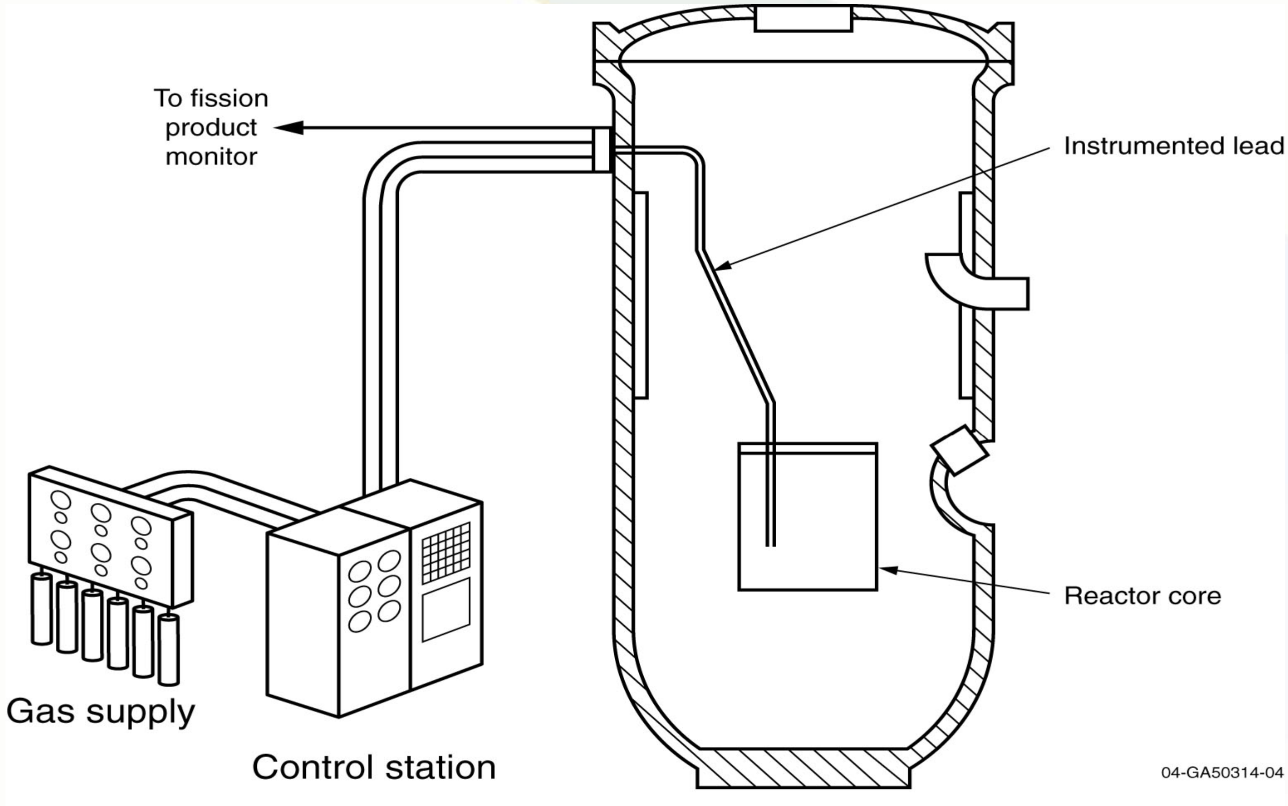
- Passive instrumentation (flux wires, melt wires)
- Temperature target controlled by varying gas mixture in conduction gap and with material selection
- Lengths up to 48”; diameter 0.5” – 5.0”
- Six month preparation



Instrumented Lead Experiments

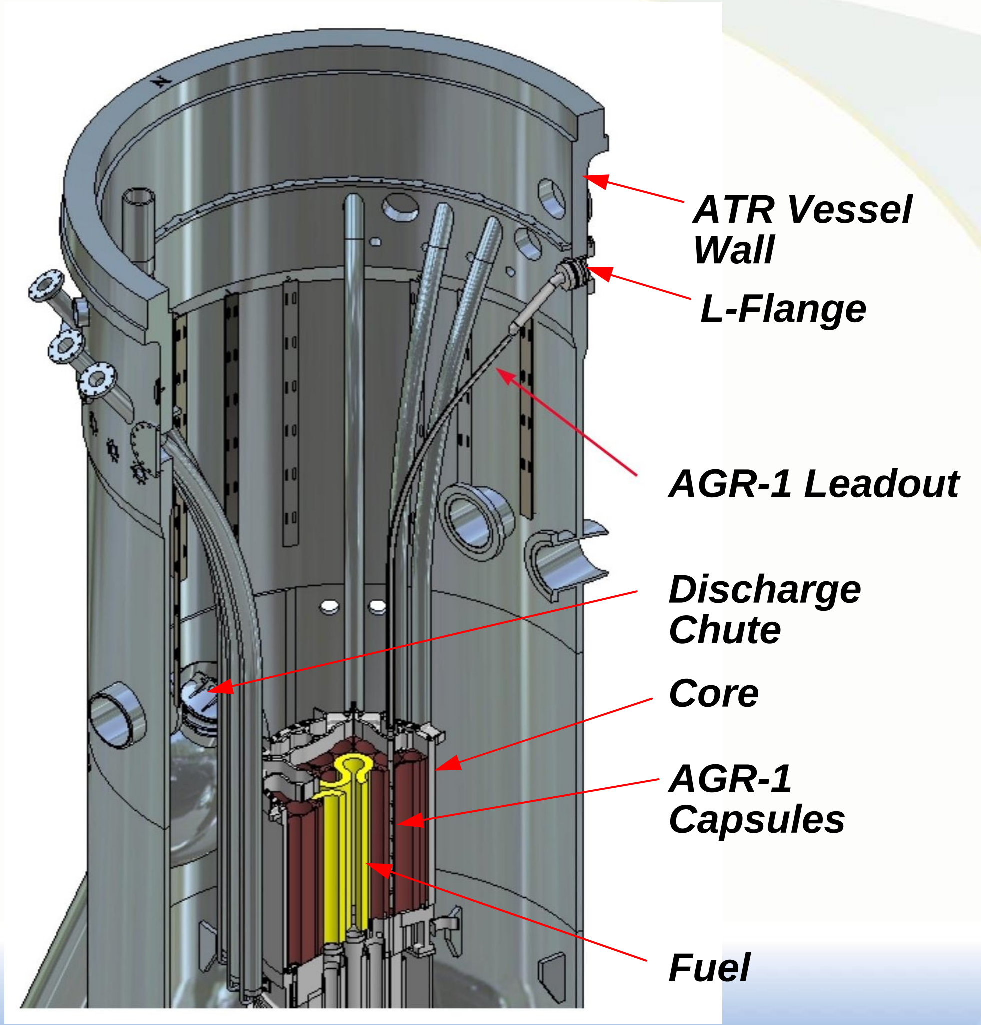
- On-line experiment measurements
- With or without active temperature control
- Temperature control range 250-1200°C, within +/- 5°C
- Monitoring of temperature control exhaust gases for experiment performance (e.g., Fission products, leaking materials, etc.)
- Specialized gas environments (oxidized, inert, etc.)
- Removal and replacement of experiment through discharge chute
- ~18 months preparation for new test design and installation

Typical Instrumented Lead Experiment Configuration



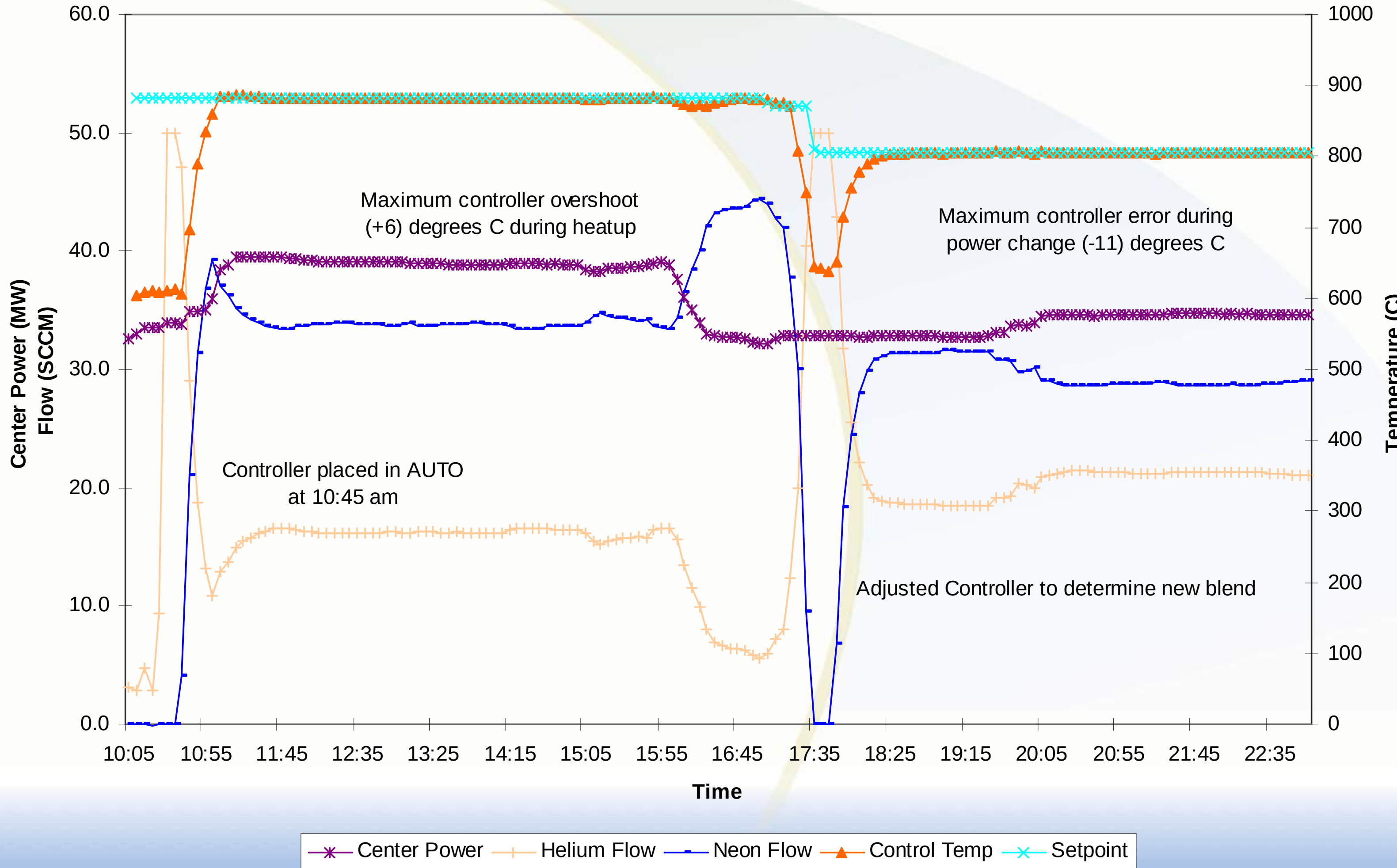
Cross section of ATR vessel

Advanced Gas Reactor Experiment



- Leadout is umbilical to experiment control system
  - Houses temperature control gas lines & thermocouples
  - Vertically locates the experiment in the ATR core
- Experiment can be removed and returned to the reactor core thru the discharge chute
- Irradiation for approximately 2 years
- Established capability for temperature control and lead experiments

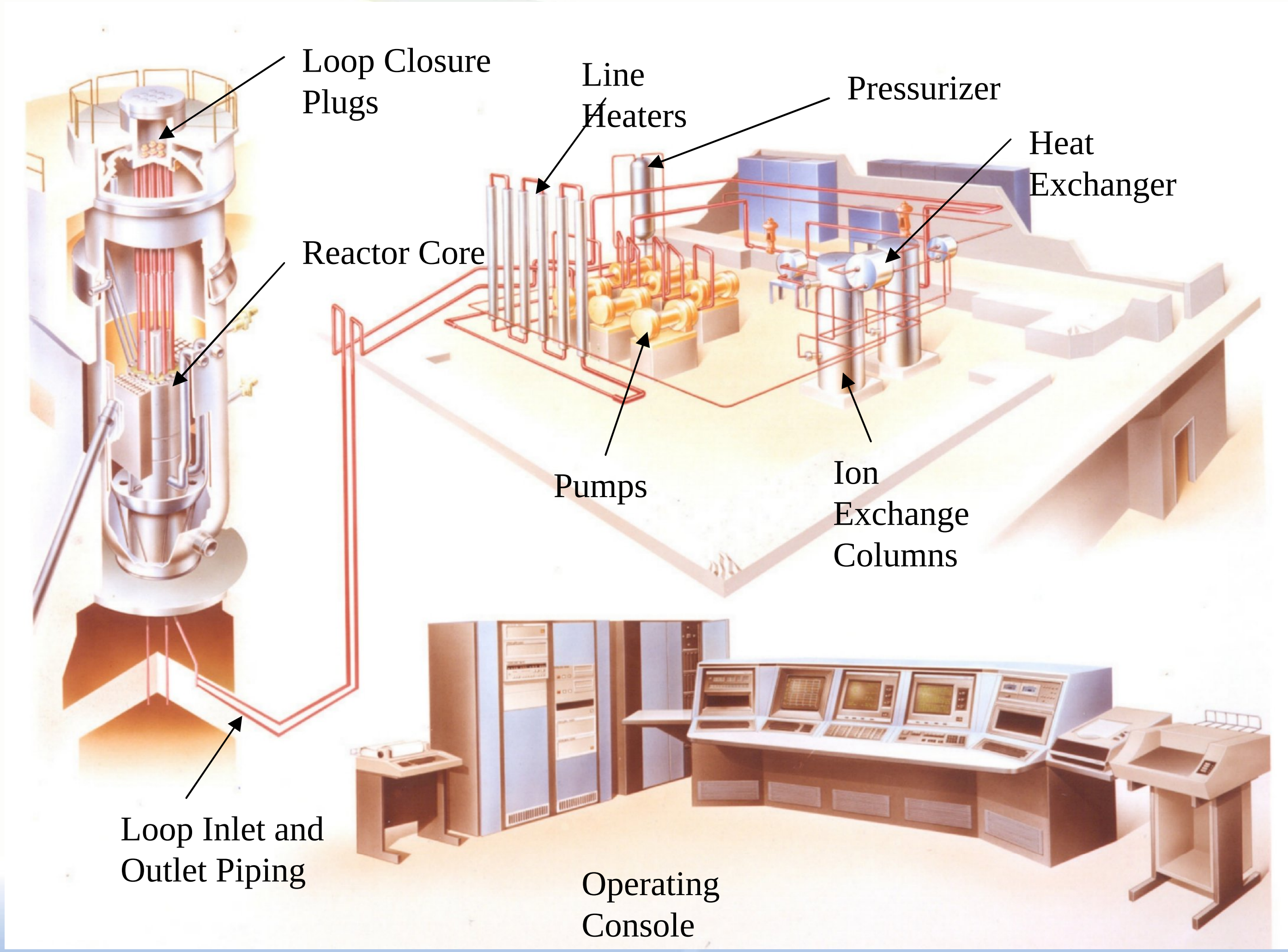
MIPT-3 Capsule 2 - Temperature Response: Initial Heat Up and Reactor Power Changes



Pressurized Water Loop Tests

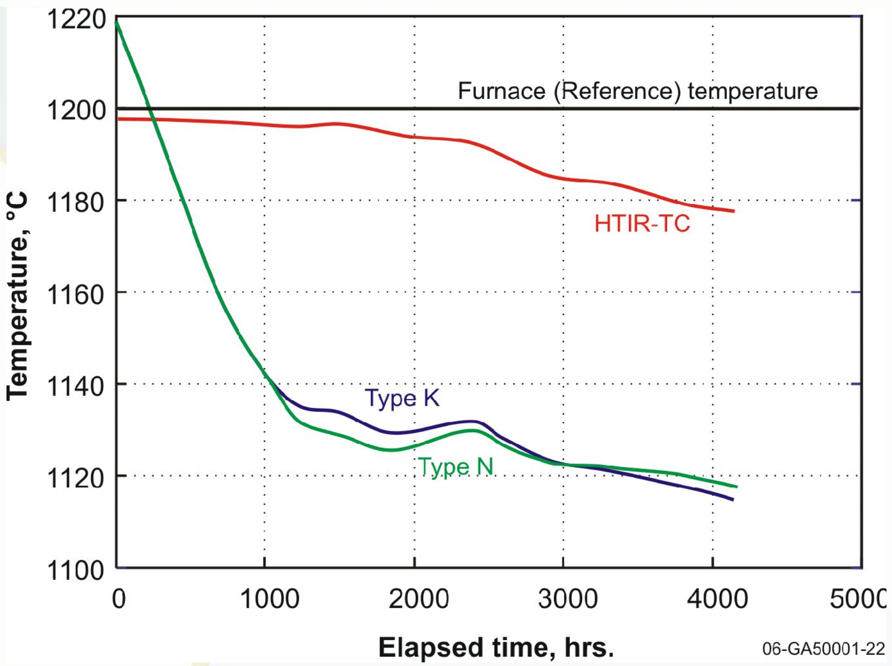
- Five flux trap positions currently have pressurized water in-pile loop tests (1 large diameter, 4 small diameter)
- Separate from ATR primary coolant system
- Each loop has its own temperature, pressure, flow, and chemistry control systems – can exceed current PWR operating conditions (2250 psig, 650F)
- Transient testing capabilities (cycle/seconds)
- Potentially feasible to simulate boiling water reactor void conditions
- Up to two year preparation for new test programs

ATR Standard Loop Layout



Experiment Measurement Capabilities

- Flux Wires
  - Co-Al
  - Fe-Ni
  - Others
- Thermocouples
- Tritium Monitors
- Moisture Monitors
- Fission Product Monitors
- Specimen Creep
  - Tension (in development)
  - Compression
- Oxidation Measurements on Graphite Experiment



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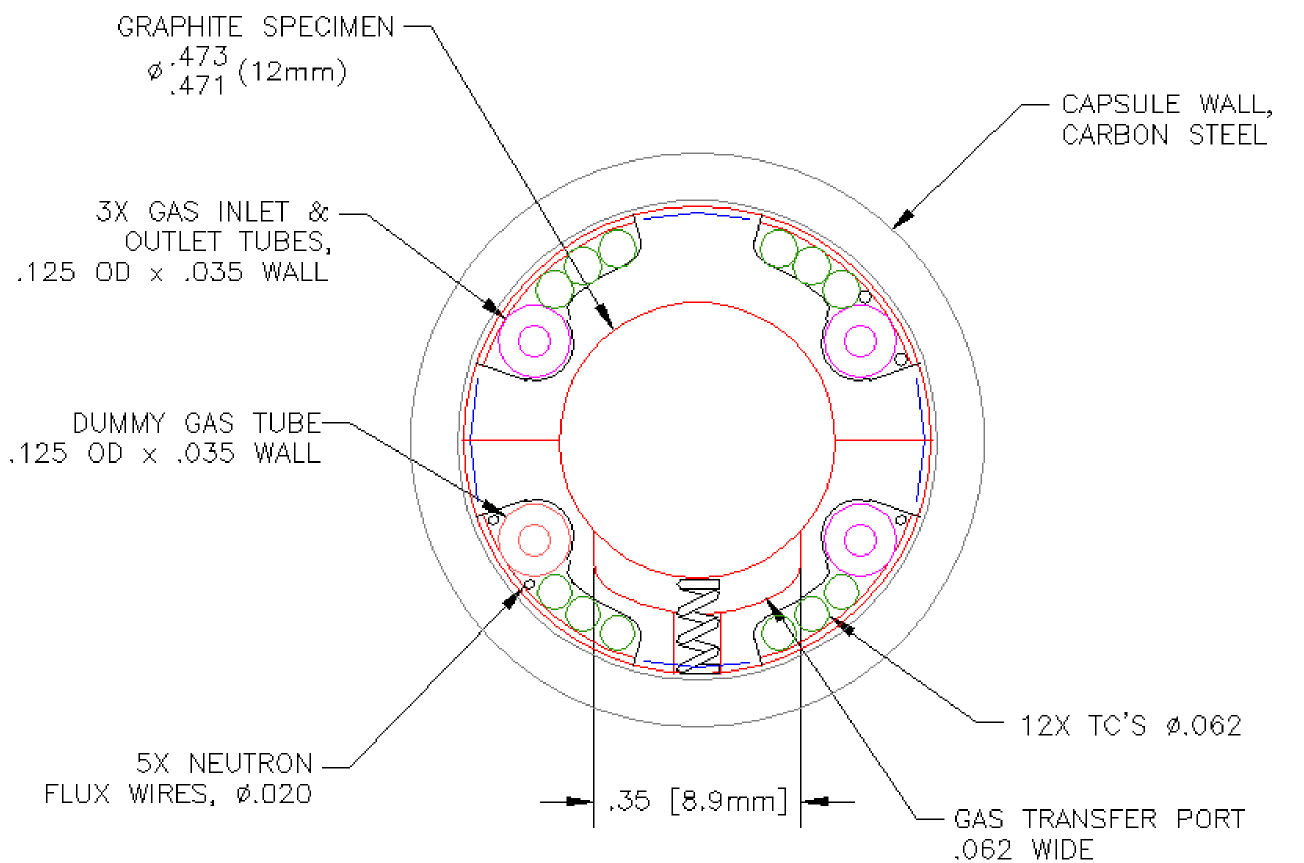
Previous Testing in the ATR

- Material and Fuels for New Production Reactor (project cancelled in 1992)
- Graphite Oxidation and Aging Studies for Magnox
- Pu-238 Production Studies
- Weapons Grade Mixed Oxide Fuel
- Reduced Enrichment for Research and Test Reactors (RERTR) – High Density, Low Enrichment Fuel
- Plant Maintenance Technology & Welding of Irradiated Materials

Magnox Graphite Irradiation

- British (Nuclear) Industry Management Committee
- Lead Experiment (gas temperature control) with graphite material specimens
- General Description/Purpose
  - Accelerated irradiation of graphite core material to support life extension of the 'Magnox' style gas reactor power stations in the UK
  - Provided the necessary data to support continued use of one of the largest Magnox reactors in the UK
- Unique Capabilities Developed/Utilized
  - Cover gas system (separate from and in addition to the temperature control gas system) to provide oxidation of the graphite specimens during irradiation
  - Variable gas gap for different temperatures at different vertical locations in the core
  - Use of the Irradiation Test Vehicle system

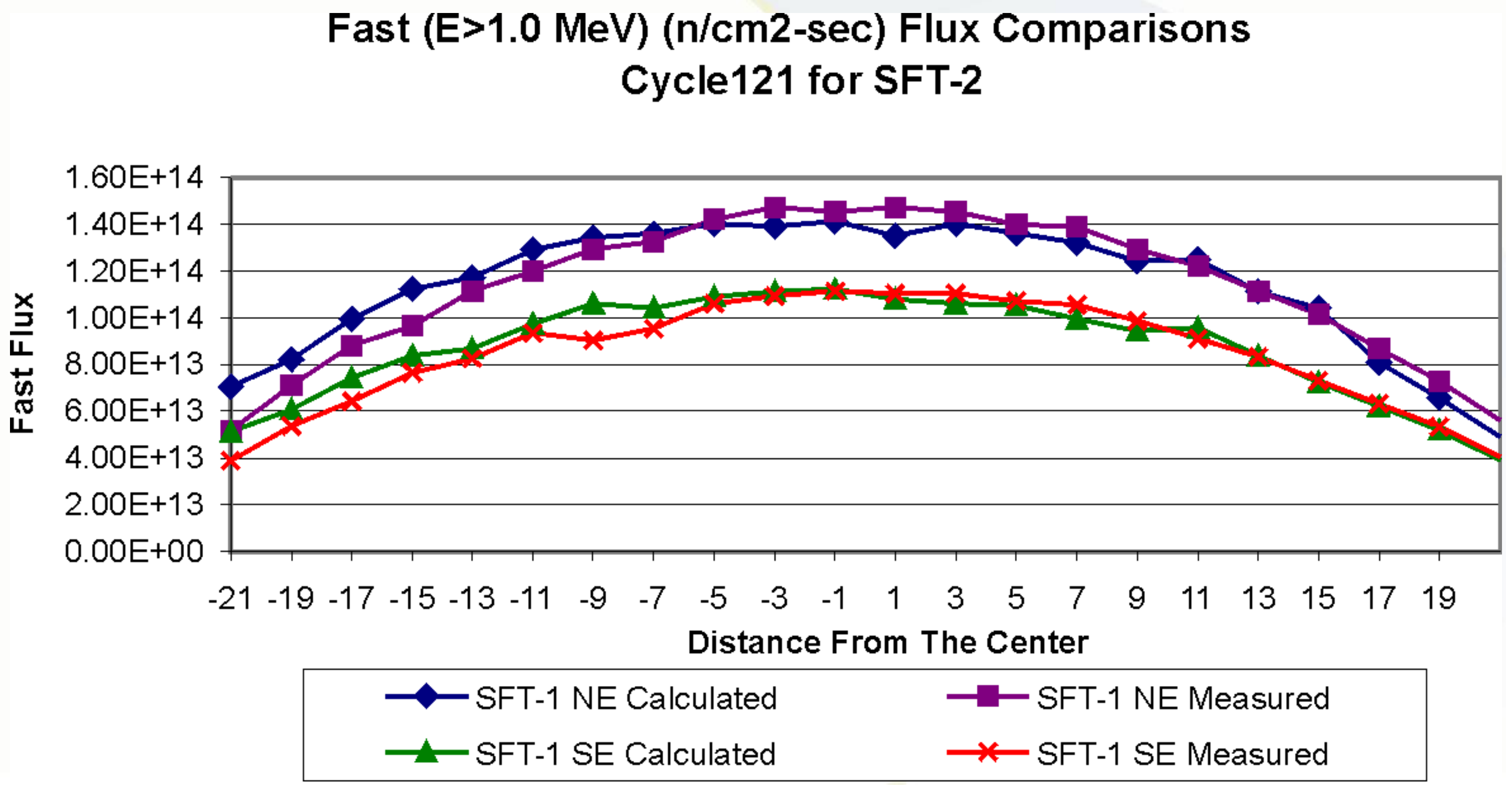
Magnox Experiment Cross Section



JAPEIC Experiment

- JAPEIC (Japanese Power Engineering and Inspection Corporation) under contract to the Japanese Government
- Static Capsule Experiment of reactor pressure vessel stainless steels
- General Description/Purpose: Welds on reactor pressure vessel steel materials were irradiated to provide information on irradiation effects on welds and weld repairs
- Unique Capabilities Developed/Utilized:
  - Flux enhancement (using booster fuel to attain an approximate three fold increase in the fast flux rate) of a Large I position was developed to irradiate the lower fluence specimens.
  - Higher fluence specimens were irradiated in the South Flux Trap

JAPEIC Measured and Calculated Flux



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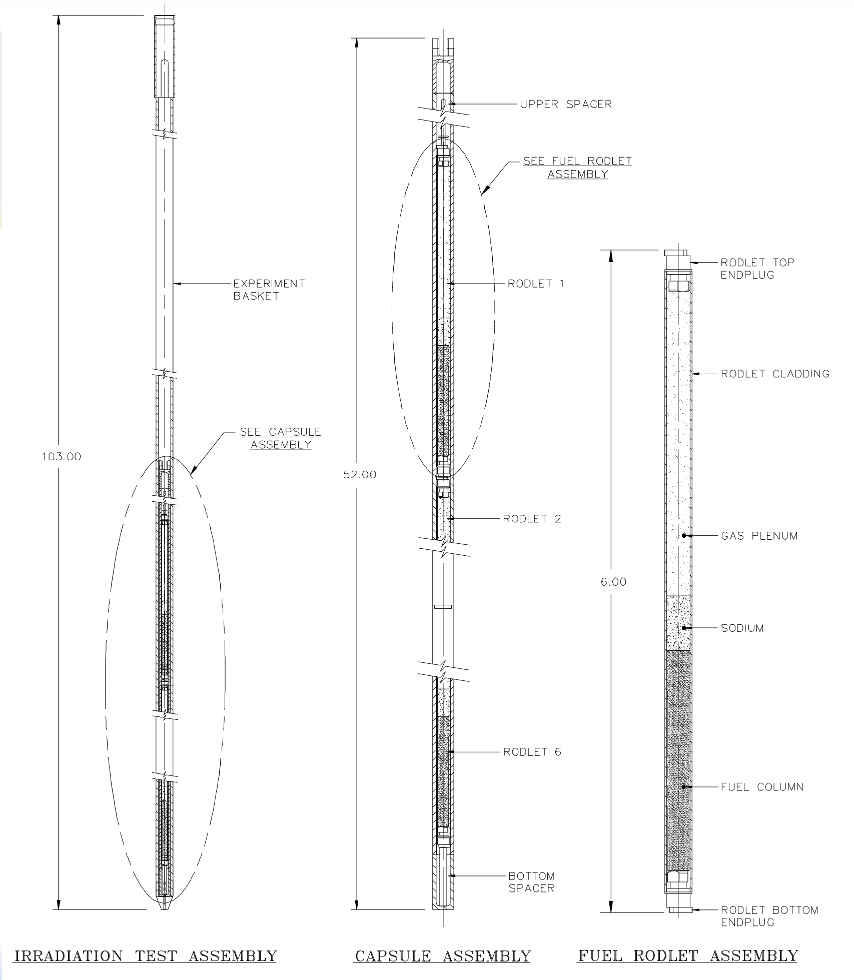
Advanced Fuel Cycle Initiative

- Static Capsule irradiations of non-fertile and low-fertile nitride and metallic fuel compositions.
- Develop and demonstrate the technologies needed to transmute the long-lived transuranic actinide isotopes contained in spent nuclear fuel into shorter-lived fission products, reduction in required design lifetime of geologic repository.
- Experiment basket designed as a thermal neutron flux filter. A hard neutron spectrum is achieved by the use of a cadmium shroud removing greater than 97% of thermal flux.



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AFCI Flux Spectra with Cadmium Sleeved Basket

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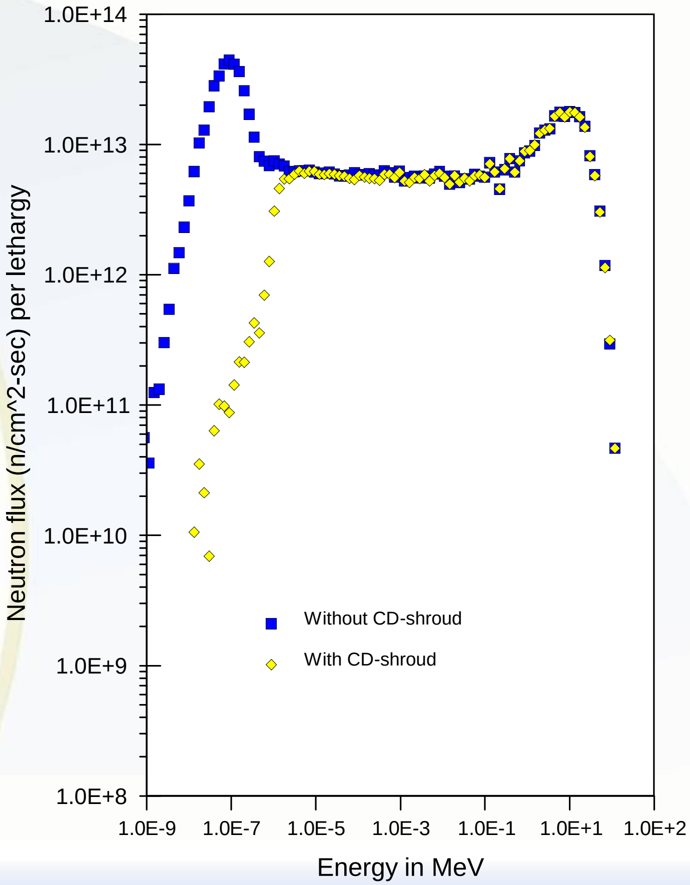
- Hard Spectrum Achieved in ATR by Use Of .045 inch Thick Cadmium
- > 97% of Thermal Flux is Removed

	Thermal neutron flux (E < 0.625 eV) n/cm^2-sec	Fast neutron flux (E > 1.0 MeV) n/cm^2-sec
With CD-shroud	8.46E+12	9.31E+13
Without CD-shroud	3.71E+14	9.39E+13
Ratio	2.28%	99.14%
Note: the flux tallies are normalized to a E-lobe power of 22 MW.		



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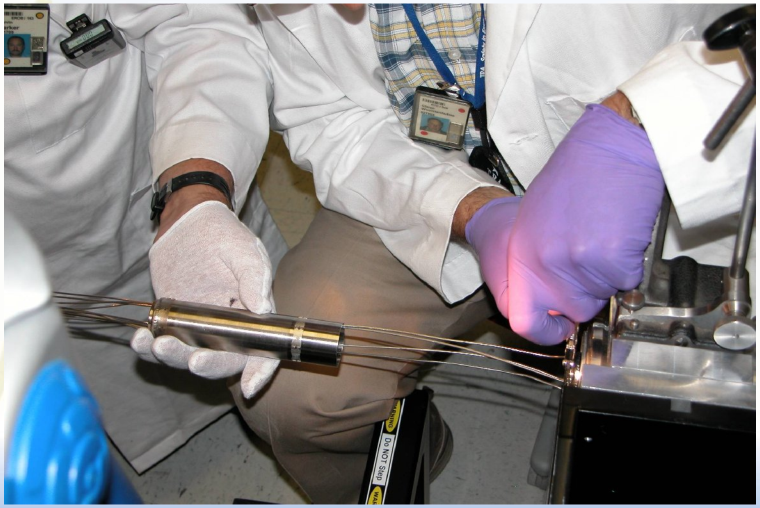
Current ATR Irradiation Projects

- Advanced Fuel Cycle - Fuel tests expected to continue through 2013
- Cobalt-60 for Medical and Industrial Applications - Ongoing
- Zirconium Tests, 1997 – 2009
- RERTR
  - Mini plate testing 2005 – 2009
  - Full fuel plate testing, 2008 – 2010
  - Full element tests 2011
- Advanced Gas Reactor,
  - Fuel Tests, 2006 – 2018
  - Graphite, 2009 – 2018
- Tritium Barrier Material, 2008 - 2011
- National Scientific User Facility, 2008 - indefinite

Test Train Assembly

- Induction brazing of instrument leads (e.g. thermocouples) to penetrate capsule boundaries
- Electro-plating, typically in support of induction brazes
- Thermocouple potting and splicing
- Heat treatment and (specimen) vacuum drying ovens
- Welding - Standard GTAW and MIG, tube welder
- Pressure and helium leak testing



Future Activities for the ATR

- Next CIC tentatively scheduled for 2014
- Reactivation of Pressurized Water Loop
  - PWR testing
  - Possibly BWR testing
- Hot Cell Upgrade - Dry packaging of ATR tests
- Operation of hydraulic shuttle irradiation system, “rabbit”
- New TTAF Building

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ATR Summary

- Unique and Versatile Capabilities
  - High flux/large test volumes
  - Simultaneous tests in different testing environments – power and flux tilt
  - Constant Axial Flux Profile
  - Routine Operating Schedule, with Frequent Experiment Changes

- Expected to Operate for Many More Years
- Aligned with INL Facilities - Test Assembly, PIE, Analytical Labs
- Designation as a National Scientific User Facility
  - Broader user community access
  - DOE-sponsored research and education

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